ence between the Å. S. and the S. I. S., was in 1912 3.27 per cent $\left[\frac{\text{S. I. S.}}{\text{Å. S.}}=1.0327\right]$.

Six years later—in the summer of 1919—I have now had the opportunity to make a new comparison between the readings of the Ångström pyrheliometer No. 158 and the Smithsonian scale at the observatory of Prof. Kimball of the U. S. Weather Bureau. A number of simultaneous readings were taken with No. 158 and the newly standardized Smithsonian Silver disk pyrheliometer No. 1. The conditions of the sky were not very favorable, very thin cirro-stratus causing irregular disturbances. No. 158 was found to read 4.9 ± 0.4 per cent lower than the Smithsonian (August 1919) $\left[\frac{\text{S. I. S.}}{\text{Å 158}}=1.049\right]$.

Immediately after my return to Sweden, No. 158 was compared by Dr. Lundblad with the Å. S. During the time of the observations the conditions of the sky were very favorable, the atmosphere being clear, the air very pure and calm weather prevailing. No. 158 was found to read 1.60 per cent ($\pm$ 0.1) lower than the Å. S. $\left[\frac{\text{Å 158}}{\text{Å. S.}}=0.984\right]$. Consequently the difference between the Å. S. and the S. I. S. is at present (in October 1919) found to be 3.23 per cent $\left[\frac{\text{S. I. S.}}{\text{Å. S.}}=1.0323\right]$.

There is an excellent agreement between this value and the one obtained 6 years ago, the difference falling much below the probable error (about $\pm$ 0.2 per cent). The result agrees further very well with results of comparisons by Marten at Potsdam, who found the difference between the Å. S. and the S. I. S. to be on the average 3.4 per cent.[3] From my comparisons it may be regarded as a safe conclusion, that neither the Ångström Standard nor the Smithsonian Standard has since 1912 been subjected to changes which practically need to be considered. The previous discussion consequently supports as well the opinions expressed by G. Granquist[4] in regard to the Ångstrom standard as those of C. G. Abbot[5] in regard to the Smithsonian one.

In a previous paper I have given reasons for assuming that 1.8 per cent of the difference between the pyrheliometer scales may be due to special features in the construction of the compensation pyrheliometer, whose readings consequently in general ought to be corrected by + 1.8 per cent. The remaining 1.5 per cent I am still inclined to believe to adhere to the Smithsonian scale, the measurements of Coblentz and of Royds having supported the value found by K. Ångstrom for the absorption power of soot and applied by him to the computed values of pyrheliometer constants.[6]

In applying given constants to pyrheliometric readings, it is, as in the case of all instruments, of great importance to make sure that the instrument itself is in unchanged condition, at least in its general and perceivable features. No one expects accurate results from the readings of a thermometer whose bulb has been broken, or a barometer whose mercury has been oxidized. In using the electrical-compensation pyrheliometer it is important to make sure that the strips are straight, uniformly black, and adhering to the supporting frame. An important source of error may arise from the fact that the measurements involve the use of a millammeter for reading the compensation current. Generally these millammeters are good and their temperature coefficient negligible—at least my own experience with the millammeters of Siemens and Halske and of Weston Electrical Instrument Company has been highly satisfactory. But it sometimes occurs that instruments even of the best make will show considerable errors, especially with change in temperature, and a control is therefore necessary. Especially the ammeters, which on expeditions are carried along with a pyrheliometer, need control through comparisons with other instruments or through new standardization at certain intervals. These precautions taken, the electrical compensation pyrheliometers seem, according to my experience, to be constant in their readings. Their disadvantage compared with the Smithsonian secondaries lies in their more delicate construction and their need of auxiliary instruments. Their chief advantage lies in the possibility of controlling the constant determination by measuring the width and resistance of the strips, which ought to be possible at every well-furnished physical laboratory; and, further, in the possibility of giving almost momentary values of radiation, which is especially important when one attempts to measure, for instance, the transmission of clouds, or tries to follow rapid variations in the radiation.

To Dr. Abbot, Prof. Kimball, Dr. Lindholm and Dr. Lundblad, my thanks are due for assistance in comparisons.

[3] W. Marten: Messunger der Sownerstrahlung in Potsdam in der Jahren 1909 bis 1912. (Veröff. des Königl. Preuss. Meteor. Inst., No. 267).

[4] Bericht über die erste Tagung der Strahlungs Kommision des internationalen Meteor. Komitees in Rapperswyl bei Zürich in September, 1912, Anhang IV, 1912.

[5] *Abbot and Aldrich:* Smithsonian Misc. Coll. Bd. 60, 1913.

[6] W. W. Coblentz: Bull. of Bureau of Standards, *9*, 193. Royds: Phys. Zeitschrift 1910, p. 316.

COMPARISON OF METHODS FOR COMPUTING DAILY MEAN TEMPERATURES: EFFECT OF DISCREPANCIES UPON INVESTIGATIONS OF CLIMATOLOGISTS AND BIOLOGISTS.

By F. Z. HARTZELL, Associate Entomologist.

(Author's abstract of Technical Bulletin No. 68, N. Y. Agricultural Experiment Station, Geneva, N. Y., June, 1919, 8°, 35 pp., 19 figs.)

[Dated: Vineyard Laboratory, Agricultural Experiment Station, Fredonia, N. Y., Nov. 8, 1919.]

The daily mean temperature is the thermal time unit in most general use among climatologists and ecological workers in botany and zoology; and, usually, this average is computed from maximum and minimum readings taken at some convenient hour. The true daily mean temperature is secured by mechanically integrating, with a planimeter, the corrected thermograph curve of the drum type of thermograph, or, in any case, by summing the average hourly temperatures, and dividing the result by 24 in every case. This mean is designated the thermograph average, while the approximate mean, computed from maximum and minimum readings, is known by the hour at which the observations were recorded; viz, the midnight, 12 p. m., 8 p. m., or 5 p. m. average.

It was found that the thermograph average seldom was the same as any of the corresponding approximate averages. The differences have been designated "discrepancies"; which are positive if the given average is greater than the thermograph average; negative, if less. The discrepancies for the various averages at Fredonia, N. Y. (Lake Erie Valley), for every day of 1916, were investigated by means of the statistical methods of Pearson.

In order to analyze the data, so as to determine the effect of the discrepancies on the mean annual temperature, the discrepancies for each series of averages were combined in frequency polygons, and the theoretical curves fitted to the observations. Owing to the extreme variations in the range of the several distributions it was necessary to use different units of grouping, which fact must be borne in mind in comparing the several polygons. Convenient intervals for grouping were found to be: For the 5 p. m. discrepancies, 2.0°; for the 8 p. m., 1.5°; for midnight, 0.8°. The several frequency polygons and their theoretical curves are shown in figures 1 to 3. The fitted curves are of Pearson's type IV.

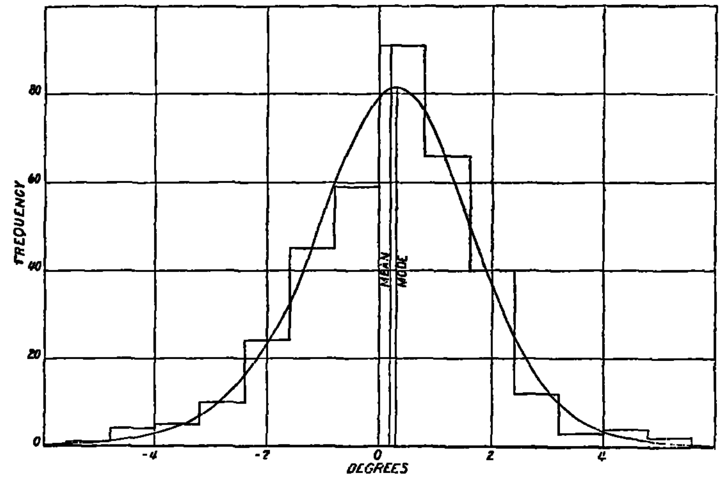

FIG. 1.—Histogram and fitted curve of variation in daily discrepancy. Midnight record. Fredonia, N. Y., 1916.

On the basis of a year's record, it was found that: (1) Small discrepancies occur more frequently than large ones; (2) within the limits of the times of observations used in this study, the time of observation determines the probability of large discrepancies, the 5 o'clock averages producing many more large values than observations made later in the day produced; (3) positive

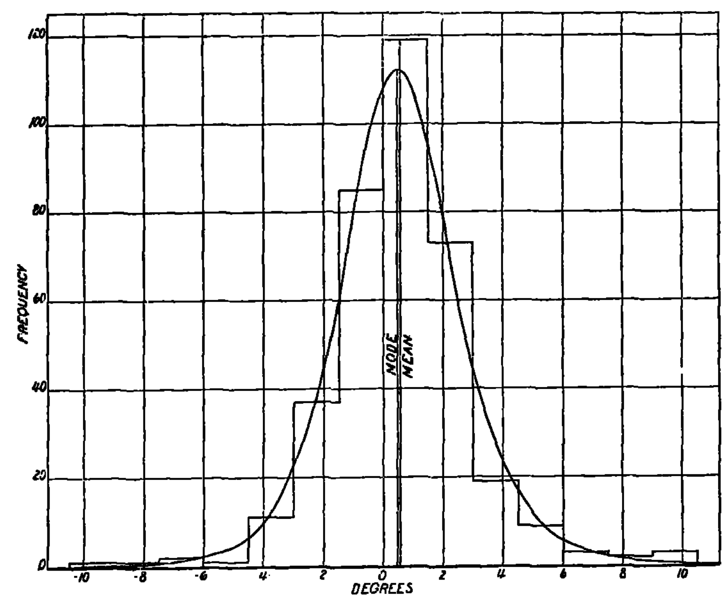

FIG. 2.—Histogram and fitted curve of variation in daily discrepancy, 8 p. m. record. Fredonia, N. Y., 1916.

discrepancies are of more frequent occurrence than negative ones, thus causing the approximate mean annual temperature to be too high; these differences are greater the earlier the hour of observation; (4) no method of using maximum and minimum temperatures is as exact as that based on the summation of hourly temperatures or as the integration of the thermograph curve.

The discrepancies in the annual mean temperature are: For the 5 p. m. observations, 1.21±0.11°; 8 p. m., 0.58±0.08°; midnight, 0.20±0.056°. Thus, from a practical viewpoint, averages of daily maximum and minimum temperatures, when the observations are made not earlier than 8 p. m., affect the annual mean temperature so slightly that the differences are negligible for all purposes, but averages for observations earlier than this hour introduce differences that may be important in some studies. A study of the standard deviations of the discrepancies supports these conclusions. Figures 1 to 3 show the ranges.

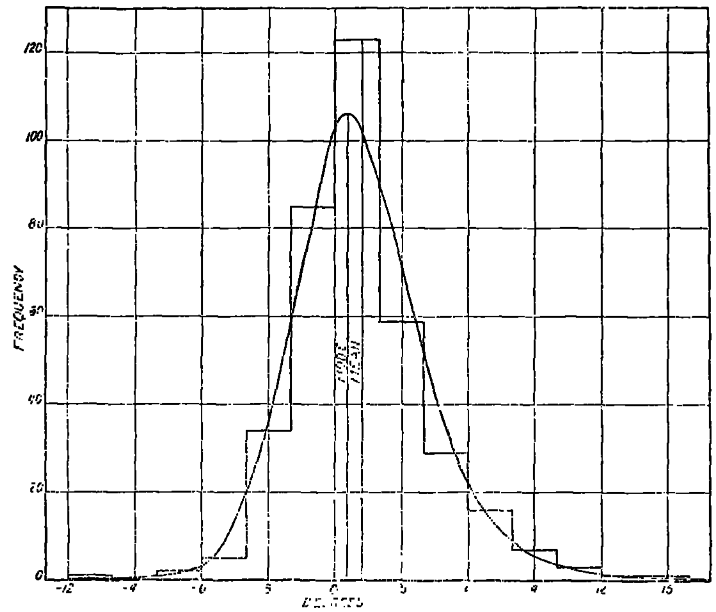

FIG. 3.—Histogram and fitted curve of variation in daily discrepancy, 5 p. m. record. Fredonia, N. Y., 1916.

The greatest discrepancies occurred on the days of the winter months, and the smallest during the summer months. July showed the smallest deviations. This is because the disturbances superposed upon the normal diurnal temperature curve are most pronounced and irregular during the winter. The discrepancies introduced into the mean monthly temperatures by the several series of observations are shown in figure 4. For

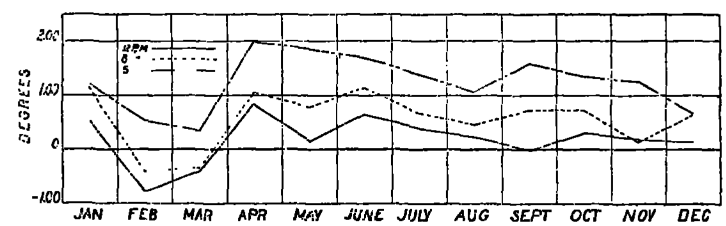

FIG. 4.—Graph showing the variation in average monthly discrepancies during 1916. Fredonia, N. Y.

meteorological purposes, these were perhaps not excessive when the hour of observation was not earlier than 8 p. m., but, for biological purposes, it is advisable to use thermograph averages.

The differences in the mean daily temperature between successive days of the month were calculated for each series of observations, and it was found that on many days the divergencies were excessive in every record. The only mean that can be depended upon for the investigation of either climatology or biology, when daily differences are to be compared, is that given by the thermograph average. Owing to the extreme variation in the discrepancies from day to day, the use of the shorter method of computing means may introduce errors which will mask relationships between thermal influence and biological activity.

Perhaps the chief result of this study is the proof of the fact that *if approximate averages are employed, the same hour of observation should be used if the data are expected to be comparable.* The taking of readings before 8 o'clock in the evening is not to be recommended for *any* purpose, owing to the extreme differences that will be introduced in the averages.

When daily means are used in the summation of effective temperatures, or of temperature co-efficients, for the study of thermal influence in botany and zoology, thermograph averages alone should be used, since approximate means introduce rather large errors, especially during the spring months, as is shown in Table 1.

The U. S. Weather Bureau practice being to average the temperature extremes from midnight to midnight, the normals so computed are adequate for meteorological purposes. In the case of cooperative observers, who have no thermograph record by which to do this, records taken at 8 o'clock in the evening appear to be the most desirable if maximum and minimum thermometers are in use, since the errors of computation introduced are not excessive, and the hour is convenient for the observer. When the variation of the exposure of the instruments is considered, it is doubtful whether any important gain in the accuracy in the mean temperature for a month would be secured by furnishing cooperative observers with thermographs. Such are essential for biological purposes, however.

TABLE 1.—*Summation of daily mean temperatures above 39° F., Fredonia, N. Y., 1916.*

(From Apr. 11 to the end of the month indicated.)

Record.	April.		May.		June.		July.		August.	
	Summation.	Per cent discrepancy.	Summation.	Per cent discrepancy.	Summation.	Per cent discrepancy.	Summation.	Per cent discrepancy.	Summation.	Per cent discrepancy.
	°F.		°F.		°F.		°F.		°F.	
Thermograph	151.7	0	654.9	0	1,337	0	2,474	0	3,505	0
Midnight	164.5	8.4	672.5	2.7	1,374	2.7	2,523	1.9	3,561	1.6
8 p. m.	166.5	9.8	694.0	6.0	1,410	5.5	2,568	3.8	3,613	3.1
5 p. m.	183.5	20.9	744.5	13.7	1,477	10.5	2,657	7.4	3,721	6.1

PARADE-GROUND TEMPERATURES AT COLLEGE STATION, TEX.

By CHARLES F. BROOKS.

In June, 1918, at College Station, Tex., some observations were made of parade-ground temperatures under different conditions of cloudiness, and were also compared with temperatures in the grass and air. The instrument was a physical thermometer upon which the boiling point was about 101.5° C., and the freezing point at 0.2° C. The temperatures mentioned below are uncorrected for instrumental error. The influence on the dust temperature of the passage of the shadow of a cumulus cloud is shown in the following table:

About sunrise the next morning it was found that the temperature in the dust was about 27.8° C., in the air about 1 meter above the ground, 25.9° C., and in the grass 24.7° C. In the afternoon, with the thermometer placed under 2 or 3 mm. of dust, a temperature of 61.3 C°. (142° F.) was obtained; in the grass 48.6° C. (120° F.); in the air about 38° C. (101° F.). In this case it is noted that the breeze seemed to make little difference with the temperatures of the dust. The maximum temperature was obtained when the thermometer was placed in a dust hole slope normal to the sun's rays. A temperature of 61.7° C., or about 143° F., was obtained.

TABLE 1.—*June 18, 1918.*

Time (p.m.).	Thermometer.	Remarks.
	° C.	
3:08	59.5	Exposed in gray dust at depth of ½ cm. for 5 minutes. Sun had been shining for some time.
3:09	53.1	Beginning of cumulus shadow.
3:17	53.1	In cloud shadow. Sky cover 0.6 St.Cu., 0.2 Ci.St.
3:20	51.9	Still in shadow.
3:21	51.6	Do.
3:22	51.3	Do.
3:22:30	51.1	Sun reappearing.
3:23:30	52.4	Strong sunlight.
3:24:30	53.6	Do.
3:25:30	54.7	Do.
3:27:30	45.3	Under green grass, about 1 cm. from top of grass, and so placed that direct sunlight did not strike bulb. In poor air circulation. Strong sunlight.
3:38	43.8	Same exposure.
3:29	42.8	Do.
3:29:30	42.2	Light clouds.
3:30	41.7	Do.
3:31	40.8	Very light clouds.
3:32	40.5	Beginning of thick cloud. Gusty east wind.
3:45	38.5	Air temperature on roof of three-story building in thermometer shelter.

HIGH RELATIVE TEMPERATURES OF PAVEMENT SURFACES.

By G. S. EATON.

[Abstracted from the Engineering News-Record, Mar. 27, 1919, p. 633.]

Maximum temperatures, relatively high with respect to adjacent locations, were found by engineers of the Universal Portland Cement Co., on asphalt, brick, and concrete surfaces. From 11 a. m. to 6:30 p. m. the average readings for the three types of surfaces in the order named were 118°, 113°, and 108°. This is of special interest with respect to the effect of these high temperatures on rubber tires, horses' hoofs, and shoe leather. It is known that a large part of the tire trouble experienced by motorists is due to expansion of the air due to heat. High pavement temperatures would doubtless play a large part in aggravating this condition.

"During the middle of the day the effect of the pavements in heating the air above them was noticeable, as thermometers 1 foot and 4 feet above the roadways read from 3½ to 4½° higher than over a lawn in the sun. Temperatures above the pavements were found to be much the same, however, regardless of the type of surface. Over the asphalt, the readings averaged 1° higher than above the concrete and one-half degree higher than above the brick. After 7:30 p. m. the temperatures above the surfaces were practically the same as those of the surrounding air. The presence of large lawns and shade trees probably hastened the cooling and somewhat different results might be ex-